

2715C 2

bp



**CERTIFIED MAIL
RETURN RECEIPT REQUESTED**

BP Products North America Inc.
Whiting Business Unit
2815 Indianapolis Blvd.
PO Box 710
Whiting, IN 46394-0710

August 6, 2004

Mr. Andy Stinchfield
Emergency Response Commission
Indiana Department of Environmental Management
100 North Senate Avenue, PO Box 7024
Indianapolis, Indiana 46206-7024

Dear Mr. Stinchfield:

**RE: Case#731437 Oil Sheen on Lake Michigan, NPDES Permit No. IN 0000108
outfall 002**

On August 10, 2004 at approximately 6:30 PM, at the BP Products North America, (BP) Whiting Business Unit Lakefront Wastewater Treatment Plant, it was noticed that a slight visible oil sheen could be seen on Lake Michigan from our once through cooling water, outfall 002. Containment and recovery of the oil release began immediately. Our on site hazmat team responded to investigate the cause and mitigate the release. Our once through cooling water separator level was raised and oil removal with vacuum trucks and oil pads was initiated along with an oil boom deployment to the lake. Further investigation is currently underway to determine how the oil entered our once through cooling system.

As of the morning of Wednesday August 11, 2004 the oil sheen had been removed and the outfall discharge had no oil or other substances in amounts sufficient to create a visible film or sheen on the receiving waters. There were no other NPDES permit limit violations.

The initial estimate at the time of the incident was 41 gallons. However after reviewing guidance documents on estimating releases of oil, it is reasonable to assume that less than 1 gallon of oil was actually released.

BP personnel notified the following agencies due to the potential impact:

- National Response Center at 7:05 pm, case #731437 Mr. Crews
- IDEM Emergency Response, at 7:09 pm called back at 7:15pm Andy Stinchfield
- USCG at 7:11pm, call back at 7:25 pm Lt. Nussberger
- Whiting Filtration at 7:14 pm Bill (operator)
- LEPC 9:00pm Case # 040L10702

If you have any questions, please feel free to contact me at (219) 473-3287 or Rose Herrera at (219) 473-3393

Sincerely,

A handwritten signature in cursive script that reads "Linda Wilson". The signature is written in dark ink and is positioned below the word "Sincerely,".

Linda J. Wilson
Environmental Superintendent
Health, Safety, & Environment

✓C: Mr. Greg Glover, IDEM Office of Water Management

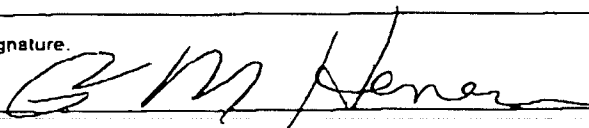


NONCOMPLIANCE NOTIFICATION FAX FORM

Indiana Department of Environmental Management
Office of Water Quality

Instructions: Complete all parts of this form and fax it to the Office of Water Quality at (317) 232-8637 or 232-8406. This report will satisfy the telephone and written noncompliance notification requirements of your NPDES permit.

Noncompliance resulting in a fish kill or other severe environmental damage must be reported to the Office of Land Quality, Emergency Response Section at: (317) 233-7745 or toll-free within Indiana at (888) 233-7745.

Facility Name: BP Products, NA	City or County: Whiting, IN Lake County	Permit Number: IN 0000108
Individual Reporting: ROSE HERRERA Richard HARRIS	Phone Number: 219-473-3321	Report Date: 12/6/04 - Initial Phone Notice 12/7/04 - phone update 12/10/04 - Final written Fax
Noncompliance Date: 12/05/04	Outfall: 001	
Parameter: TSS	Limit (Units/Daily/Weekly/Ave/Max/Min): 5694 Lbs Daily MAX	Reported: Final 6,040
Parameter:	Limit (Units/Daily/Weekly/Ave/Max/Min):	Reported:
Parameter:	Limit (Units/Daily/Weekly/Ave/Max/Min):	Reported:
Reason for Noncompliance: Exceeded TSS Daily max Loading Limit of 5,694 Lbs. Several Contributing factors at the WWTP Lead to the upset. A third party Incident Investigation is underway.		
Actions taken to prevent, minimize, or mitigate damage: Actions Taken Immediately to mitigate Further Damage was to Initiate watershed plan, reduce Process water flow rate, began water recycling, wellpoints were shutdown, manual Filter backwash was initiated.		
Actions taken to prevent reoccurrence: A third party Incident Investigation is underway.		
Signature:  for Richard HARRIS		

FAX

December 10, 2004

Mr. Greg Glover
Indiana Department of Environmental Management
Office of Water Management
100 North Senate
Indianapolis, IN 46206-6015

RE: NPDES Permit No. IN 0000108

Exceedance of Daily Maximum Limit for Total Suspended Solids at Outfall 001

Dear Mr. Glover:

This letter serves as our written follow-up to our initial phone notification on December 6 and 7, 2004, concerning the exceedance of the daily maximum limit for total suspended solids (TSS) at Outfall 001 on December 5, 2004. We became aware of the possible non-compliance at approximately 2:00 pm (CST) on December 6, 2004 when the initial composite sample analysis was completed. The initial analysis of the December 5 composite sample was 124.4 mg/l TSS.

In order to verify the above initial analytical result, subsequent internal lab analysis and third party analysis were completed on 12/7/04 and 12/9/04. When the additional analysis results were averaged with the original lab results it was verified that we had exceeded our daily maximum allowable loading rate of TSS at Outfall 001. The additional analysis was averaged with the original results from the composite sample of 12/05/04. The calculated average TSS result is now 80.5 mg/l, the calculated loading rate is estimated at 6,042 pounds, which is still above our NPDES, permit limit of 5,694 pounds TSS maximum daily load.

As a precautionary measure, BP began its water shedding plan, reduced the process water flow rates to the sewers, began water recycle, well point shutdown, performed manual backwash of the filter systems, and minimized flows to the lakefront. The watershed program is still in place as of this date and we will continue our watershed program as necessary. A third party investigation is currently being initiated to evaluate causes and actions needed to prevent re-occurrence.

Sincerely,



Ms. Rose Herrera
Acting Environmental Superintendent
BP Whiting Refinery

BCC: L. J. Wilson

R. A. Harris

File Incidents\2004

E-file I:\environmental\Incidents\2004\120502-TSSupset



Governor

Lori F. Kaplan
Commissioner

P-file Compliance
INDIANA DEPARTMENT OF ENVIRONMENTAL MANAGEMENT
We make Indiana a cleaner, healthier place to live.

100 North Senate Avenue
P. O. Box 6015
Indianapolis, Indiana 46206-6015
(317) 232-8603
(800) 451-6027
www.state.in.us/idem

March 10, 2003

Karleen James
Environmental Superintendent, HSE
BP Products North America, Inc.
Whiting Business Unit
2815 Indianapolis Blvd.
P.O. Box 710
Whiting, Indiana 46394-0710

Re: February 28, 2003 Letter
BP (Amoco) Whiting Unit – Lake Co.
NPDES Permit No. IN0000108

Dear Ms. James:

I have received your response to the above-mentioned letter. The response is adequate. This agency looks forward to your continued compliance, and if you have any questions, you may call me at (317) 232-8630, or write to me at the above address.

Sincerely,

Greg Glover
Senior Environmental Manager
Compliance Evaluation Section
Office of Water Quality

VOLUME II

NPDES PERMIT RENEWAL APPLICATION

MIXING ZONE DEMONSTRATION

Prepared for:

AMOCO OIL COMPANY
Whiting Refinery
Whiting, Indiana

Prepared by:

The ADVENT Group, Inc.
1925 Lynn Street, Suite 702
Rosslyn, VA 22209

Advanced Aquatic Technology Associates, Inc.
748 Whalers Way, Bldg. D, Suite 200
Fort Collins, CO 80525

August 1994

TABLE OF CONTENTS

<u>Section</u>	<u>Title</u>	<u>Page No.</u>
	TABLE OF CONTENTS	i
	LIST OF TABLES	iii
	LIST OF FIGURES	iv
	FOREWORD	v
1	INTRODUCTION	
	FACILITY DESCRIPTION	1-1
	WATER QUALITY MANAGEMENT PROGRAM	1-3
	BASIS FOR ALLOWANCE OF A MIXING ZONE	1-3
	Federal Regulations and Guidance	1-7
	General Mixing Zone Characteristics	1-9
	Jet Momentum Zone	1-9
	Intermediate Mixing Zone	1-11
	Far-Field Mixing Zone	1-11
	Mixing Zone Specifications	1-12
	INDIANA MIXING ZONE LAWS	1-14
	APPLICABILITY OF MIXING ZONE FOR THE AMOCO WHITING REFINERY	1-17
2	MIXING ZONE DELINEATION	
	INITIAL MIXING ZONE ANALYSIS	2-1
	MIXING ZONE FIELD STUDY	2-2
	Methodology	2-3
	Mixing Zone Field Study Conclusions	2-3
3	MIXING ZONE DISPERSION ANALYSIS	
	MULTIPOINT DIFFUSER MODELING	3-1
	Model Input Parameters and Diffuser Design	3-3
	Model Results	3-5
	SUMMARY	3-5
4	MIXING ZONE DEMONSTRATION	
	INTRODUCTION	4-1
	INDIANA MIXING ZONE REGULATORY REQUIREMENTS	4-1
	327 IAC 2-1-4(b)(1) - The Dilution Ratio	4-3
	327 IAC 2-1-4(b)(2) - The Physical, Chemical, and Biological Characteristics of the Receiving Body of Water	4-4

TABLE OF CONTENTS

<u>Section No.</u>	<u>Title</u>	<u>Page No.</u>
	327 IAC 2-1-4(b)(3) - The Physical, Chemical, and Biological Characteristics of the Waste Effluent	4-11
	327 IAC 2-1-4(b)(4) - The Present and Anticipated Uses of the Receiving Body of Water	4-12
	327 IAC 2-1-4(b)(5) - The Measured or Anticipated Effect of the Discharge on the Quality of the Receiving Body of Water	4-13
	327 IAC 2-1-4(b)(6) - The Existence of and Impact Upon any Spawning or any Nursery Areas of Any Indigenous Aquatic Species	4-22
	327 IAC 2-1-4(b)(7) - Any Obstruction of Migratory Routes of Any Indigenous Aquatic Species	4-23
	327 IAC 2-1-4(b)(8) - The synergistic effects of Overlapping Mixing Zones or the Aggregate Effects of Adjacent Mixing Zones	4-24
	OVERALL SUMMARY.	4-25
5	MIXING ZONE DEMONSTRATION CONCLUSION	5-1
6	RECOMMENDATION	6-1
ATTACHMENT 1	WIND ROSE	
ATTACHMENT 2	CORMIX MODEL OUTPUT	
ATTACHMENT 3	PRELIMINARY DIFFUSER DESIGN	
ATTACHMENT 4	SOUTH END OF LAKE MICHIGAN BIBLIOGRAPHY	
ATTACHMENT 5	BIOASSESSMENT DATA SUMMARY	
ATTACHMENT 6	STORET SYSTEM RETRIEVAL FOR WHITING INTAKE	
ATTACHMENT 7	REPRESENTATIVE FISHERIES	

LIST OF TABLES

<u>Table No.</u>	<u>Title</u>
1-1	NPDES Outfall 001 Discharge Limitations and Effluent Quality
1-2	Water Quality Management Program Elements
1-3	Mixing Zone Terminology
1-4	Indiana Water Quality Standards
1-5	Federal and Indiana Mixing Zone Specifications
3-1	Port Sizes and Spacing for a 90-ft Multiport Diffuser
3-2	CORMIX2 Model Input Parameters
3-3	Lake Michigan Water Quality Data
3-4	Summary of Lake Michigan Current Measurements
4-1	Comparison of Outfall 001 Characteristics to Federal Primary Drinking Water Standards
4-2	Data Summary Chart

LIST OF FIGURES

<u>Figure No.</u>	<u>Title</u>
1-1	Location Map, Whiting, Indiana
1-2	Area Map, Amoco Oil Company - Whiting Refinery
1-3	Wastewater Treatment Plant - Water Flow Diagram Amoco Oil Company - Whiting Refinery
1-4	Looking Toward Amoco Lakefront Wastewater Treatment Plant Outfalls Located on-Shore Photo Center Left Looking From Shore Towards Lake Front and Lake Michigan Outfalls at Photo Center Left
1-5	Outfall 002 Viewed from Lake Outfall 001 Viewed from Lake
2-1	Plume Projections - Plan View Wind Direction = South
3-1	Bathymetric Profiles of Lake Michigan near Amoco - Whiting Refinery
3-2	CORMIX2 Results for Multiport Diffuser

FOREWORD

This report is Volume II of the Amoco Oil Company, Whiting Refinery, application to renew NPDES Permit Number IN0000108.

This report provides information to demonstrate that a mixing zone can safely be integrated into the renewed Amoco NPDES Permit. This mixing zone demonstration addresses the requirements of state and federal law and guidance. Amoco is providing information based on field hydrodynamic and biological studies, chemical and biological laboratory tests, computer modeling, and literature on the physical, chemical, and biological characteristics of the receiving water, effluent, and the specific areas of the mixing zone. The studies show that Amoco's existing discharge of treated effluent (Outfall 001) provides sufficient mixing to assure attainment of water quality standards. As added environmental protection, Amoco intends to install and operate a multiport high-rate diffuser to discharge its treated effluent. A multiport high-rate diffuser will assure rapid and immediate mixing, thus further minimizing potential aquatic organism exposure. Based on the information provided in this report in accordance with regulatory guidance, a mixing zone, as delineated by Amoco, will not cause harm to human health and aquatic life.

The report is organized into the following sections:

- Section 1 introduces background information on the Amoco Whiting facility, the technical and regulatory bases for allowing a regulatory mixing zone in Lake Michigan, and the applicability of a regulatory mixing zone to Amoco's NPDES permit.
- Section 2 delineates the mixing zone resulting from the existing Outfall 001, using both field study data and computer modeling.
- Section 3 analyzes the mixing zone dispersion of the proposed multiport high-rate diffuser, using a USEPA-supported computer model.
- Section 4 demonstrates that a mixing zone meets all Indiana Mixing Zone Guidelines, which are consistent with federal guidance. This includes information on the magnitude and extent of the mixing zone, receiving water and effluent characteristics, and the results of the bioassessment field study.
- Section 5 summarizes the findings of this mixing zone demonstration and concludes that the Amoco mixing zone will not cause harm to human health and aquatic life.
- Section 6 recommends the specific mixing zone (size and dispersion ratio) to be incorporated into wasteload allocation procedures necessary to derive water quality-based effluent limits for the NPDES Permit renewal process.

TABLE 1-1. NPDES OUTFALL 001 DISCHARGE LIMITATIONS AND EFFLUENT QUALITY

PARAMETER	UNITS	1990 PERMIT LIMITS (a)		HISTORICAL PERFORMANCE (b)	
		MONTHLY AVERAGE	DAILY MAXIMUM	MONTHLY AVERAGE	DAILY MAXIMUM
TBOD5	lbs/day	4,161	8,164	721	3,580
TSS	lbs/day	3,646	5,694	2,059	4,904 (c)
COD	lbs/day	30,323	58,427	7,973	18,515
Oil & Grease	lbs/day	1,368	2,600	463	1,594
Phenolics (4AAP)	lbs/day	20.33	73.01	3.1	17.9
Ammonia as N	lbs/day	1,030	2,060	551	1,446
Sulfide	lbs/day	23.1	51.4	6.7	14.3
Total Chromium	lbs/day	23.90	68.53	2.4	5.3
Hexavalent Chromium	lbs/day	2.01	4.48	0.6	1.2

NOTES:

(a) 1990 Permit Limits are based upon previous permit effluent limitations since they were more stringent than BPT/BAT limit

(b) Historical performance based on monthly DMR data for April 1991 to April 1994.

(c) Daily maximum does not include a 24-hour time period when the WWTP experienced a known upset condition on (August 31, 1993)

BPT - Best Practicable Control Technology Currently Available

BAT - Best Available Technology Economically Achievable

TABLE 1-2. WATER QUALITY MANAGEMENT PROGRAM ELEMENTS

ELEMENT	DATE INITIATED	DATE COMPLETED
EFFLUENT CHARACTERIZATION	1990	Ongoing
- Chemical Specific	1991	Ongoing
- Flow/Hydraulics	1991	1993
- Whole Effluent Toxicity Studies		
TREATABILITY STUDIES	1991	1994
SOURCE CONTROL	1991	Ongoing
BENZENE NESHAP CONTROL PROJECTS	1990	1994
SARA (TRI) EMISSION REDUCTION PROJECTS	1990	Ongoing
ZEBRA MUSSEL CONTROL	1992	Ongoing
STORMWATER QUALITY CONTROL PROJECTS	1992	Ongoing
RECEIVING WATER CHARACTERIZATION	1990	1994
- Hydraulics	1991	1994
- Chemical Bioavailability	1992	1994
- Aquatic Biological Community & Habitat Characterization	1991	1994
- Background Water Quality		
POINT OF APPLICATION ESTABLISHMENT FOR IN-STREAM WATER QUALITY CRITERIA (Mixing Zone Delineation)	1990	1994
WASTELOAD ALLOCATION DETERMINATION	1992	1994
SITE-SPECIFIC WATER QUALITY CRITERIA ASSESSMENT	1991	1993

TABLE 1-3. MIXING ZONE TERMINOLOGY

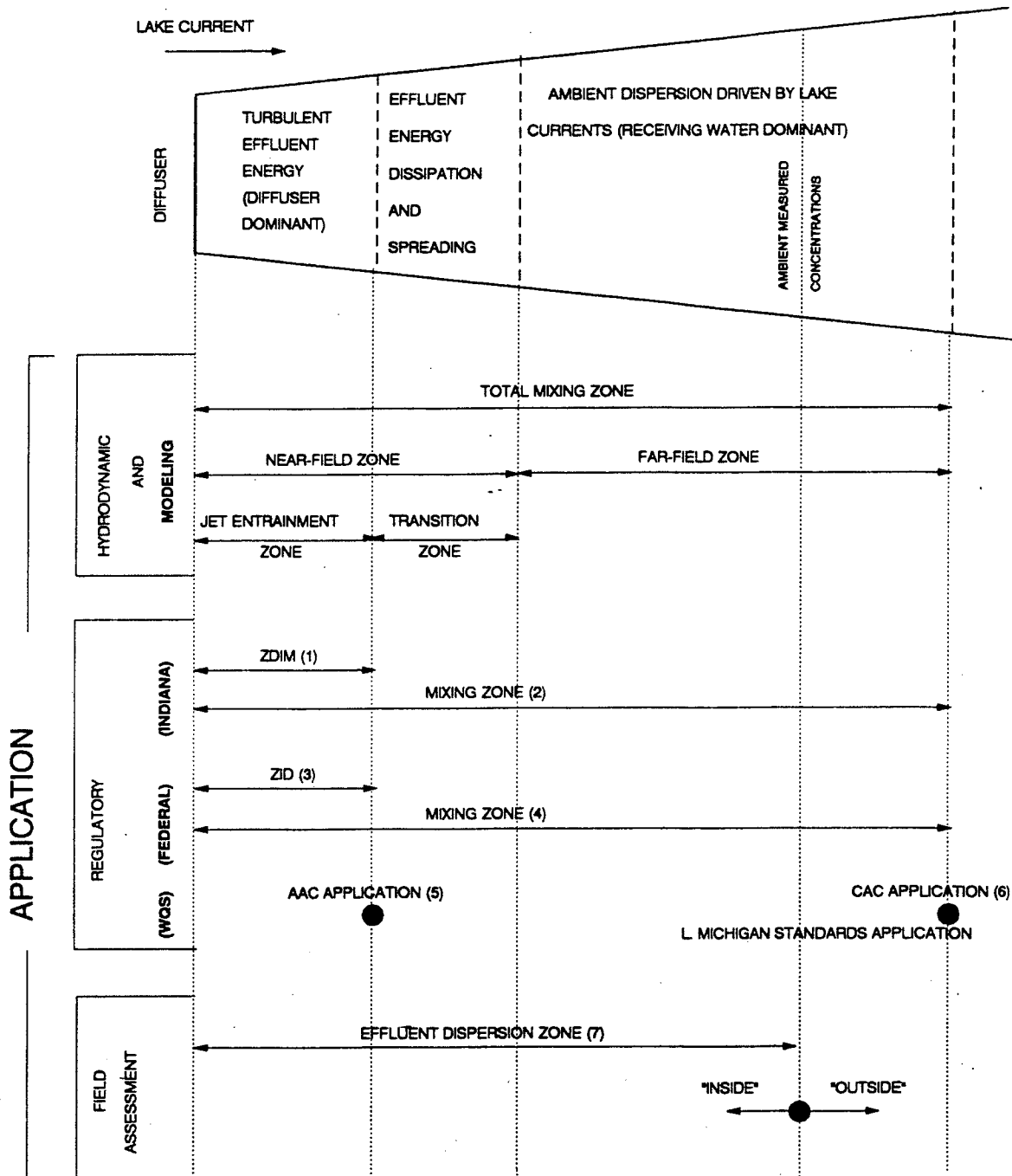


TABLE 1-3. MIXING ZONE TERMINOLOGY (continued)

FOOTNOTES	ABBREVIATION	DEFINITION
(1)	ZDIM	Zone of Discharge-Induced Mixing: to assure protection of aquatic life, concentrations of toxic substances shall not exceed the acute aquatic criterion outside this area. (327 IAC 2-1-6 (a)(1)(D)(i))
(1)	DIM	Discharge-Induced Mixing: mixing initiated by the use of submerged, high rate diffuser outfall structures which provide turbulent initial mixing and will minimize organism exposure time. (327 IAC 2-1-9)
(2)	MZ	Mixing Zone: an area contiguous to a discharge where the discharged wastewater mixes with the receiving waters. Where the quality of the effluent is lower than that of the receiving waters, it may not be possible to attain within the mixing zone all beneficial uses which are attained outside the zone. The mixing zone should not be considered a place where effluents are treated. (327 IAC 2-1-9)
(3)	ZID	Zone of Initial Dilution: a regularly shaped area surrounding the discharge structure that encompasses the regions of high pollutant concentrations under design conditions. (USEPA, 1982, Revised Section 301(h) Technical Support Document)
(4)	MZ	Mixing Zone: a limited area or volume of water where initial dilution of a discharge takes place; and where numeric water quality criteria can be exceeded but acutely toxic conditions are prevented from occurring. (40 CFR 131.35(d)(8) - Subpart D Federal Water Quality Standards)
(5)	AAC	Acute Aquatic Criteria: Receiving water application point. (327 IAC 2-1-6(a)(1)(D)(i))
(6)	CAC	Chronic Aquatic Criteria: Receiving water application point. (327 IAC 2-1-6(a)(2))
(7)	EDZ	Effluent Dispersion Zone: a field assessment zone extending from the discharge structure to a point where ambient receiving water levels or concentration are measured.

August 24, 1994

TABLE 1-4. INDIANA WATER QUALITY STANDARDS (1)

PARAMETER (2)	UNITS	AAC STANDARD	CCC STANDARD	LAKE MICHIGAN STD.			BACKGROUND CONCENTRATION (3)
				DAILY MAX	MONTHLY AVG	4-DAY CCC (4)	
<u>METALS</u>							
COPPER	µg/L	24.7	16.0				1.085
LEAD	µg/L	127.6	4.97				0.34
SELENIUM	µg/L	130.0	35.0				0.5*
ZINC	µg/L	157.5	142.7				8.81
<u>CONVENTIONALS</u>							
CYANIDE	µg/L	22.0	5.2				0.2
CHLORIDES	mg/L	860	230				11
TDS	mg/L		750				170
AMMONIA as N	mg/L			0.57	0.23		0.01
<u>NON-TOXICS</u>							
CHLORIDES	mg/L			20	15	21.3	11
IRON, DISSOLVED	µg/L			300			40
PHENOLICS	µg/L			3.0	1.0	1.42	0.17
PHOSPHORUS	µg/L			40	30	42.5	30*
SULFATES	mg/L			50.0	26.0	36.8	25
TDS	mg/L			200.0	172.0	243.6	170

NOTES:

AAC: Acute Aquatic Criteria

CCC: Continuous Chronic Criteria

(1) 327 IAC 2-1-6(a) Table 1, 2-1-6(b)(5)(C)(ii), 2-1-6(j)

(2) Standards for parameters potentially present in a refinery effluent

(3) Background concentration as presented in September 1992 IDEM WLA GCR-IHSC

* 50th percentile value from EPA STORET Database (1990 - 1993)

(4) 4-day CCC standards for 6j parameters = Lake Michigan monthly average * 1.416 (as per IDEM WLA).

Assimilative capacity is determined by comparing the 4-day CCC concentration to average background concentration. If the average background concentration is less than the 4-day CCC, then assimilative capacity is available.

Receiving Water:

Hardness = 142 mg/L

pH = 8.2 mg/L

Temperature = 22.9°C

SECTION 1

INTRODUCTION

As part of its overall water quality management program, Amoco Oil Company, Whiting Refinery (Amoco) has performed studies to assess the options available to comply with the Indiana Water Quality Standards (327 IAC 2) promulgated on March 3, 1990. These State standards have incorporated the requirements of the Federal Clean Water Act of 1987. Part of these requirements include application of water-quality based (chemical specific and whole effluent toxicity) effluent limits, as well as technology-based limits for direct dischargers. To meet the goals of the Indiana water quality standards program, Amoco developed a comprehensive water quality management program that included defining the point of application of water quality-based standards in terms of the assimilative capacity of the receiving water. Amoco requests an evaluation of the application of a mixing zone for the discharge of treated effluent into Lake Michigan as per 327 IAC 2-1-4(a), (b), and (d) and federal mixing zone guidance. Results of the dispersion analysis and corresponding mixing zone demonstration as part of this request are presented in this report.

FACILITY DESCRIPTION

The Amoco Whiting Refinery occupies approximately 1,700 acres near the southern end of Lake Michigan as presented in Figures 1-1 and 1-2. The petroleum refinery includes processes such as distillation, catalytic reforming, hydrodesulfurization, catalytic cracking, alkylation, coking, treating, extraction, dewaxing, grease and lube oil production, asphalt production, sulfur recovery, and power generation. The refining throughput varies with product demand and other market considerations, but its capacity is well over 400,000 barrels of crude per day. Amoco produces a variety of products including jet fuel, gasoline, diesel fuel, heating fuel, lubricating oils, asphalt, coke and waxes. The refinery generates

process waters which are continuously treated onsite at an advanced biological wastewater treatment plant (WWTP) as shown schematically in Figure 1-3. Stormwater run-off and recovered groundwater from refinery areas are also treated at the WWTP. The treated effluent is then discharged to Lake Michigan through a National Pollutant Discharge Elimination System (NPDES) permitted outfall (Outfall 001). The refinery withdraws Lake Michigan waters for use in process units and for once-through cooling. The once-through noncontact cooling water is discharged through NPDES Outfall 002. Both Outfalls are regulated by NPDES Permit IN0000108 (the NPDES Permit) which became effective on April 1, 1990 and expires on February 28, 1995. The effluent flow from Outfall 001 ranges from 13 (long-term average) to 23 (maximum monthly average) million gallons per day (mgd). The flow from Outfall 002 ranges from 110 to 120 mgd. Both of these outfalls are located on Figure 1-2 and pictures of the discharge structures are presented in Figures 1-4 and 1-5.

The NPDES Permit has limits for Outfall 001 derived from technology-based effluent limits, which are presented in Table 1-1. Amoco has consistently attained these permit limits with high quality effluent that meets or is below "Best Available Technology" (BAT) effluent limitations, as seen by the historical wastewater treatment plant performance also indicated in Table 1-1. It is anticipated that the new permit will contain effluent limits based on the Indiana Water Quality Standards as well as the previously applicable technology-based standards. As part of the permit renewal application, Amoco is submitting this report to demonstrate an appropriate implementation of a mixing zone for application of the Indiana water quality standards.

WATER QUALITY MANAGEMENT PROGRAM

To meet the goals of the Indiana water quality laws, Amoco developed a comprehensive water quality management program including the elements presented in Table 1-2. This report will present a discussion of the program elements relating to defining the point of application for receiving water quality criteria through delineation of a mixing zone in Lake Michigan for Outfall 001. Section 2 presents the delineation of a mixing zone for the current side-channel outfall based on both computer modeling and field studies. Section 3 presents an analysis of changing the existing discharge structure to a submerged multiport diffuser as an added margin of safety for the receiving water.

BASIS FOR ALLOWANCE OF A MIXING ZONE

In discussions of mixing zone delineation and use, not every expert uses the same terms nor are the terms defined similarly in laws. Mixing zone terminology varies with the intent and context of the discussion. For instance, the use of certain terms may depend on whether the discussion relates to engineering (hydrodynamics and modeling), field assessment (scientific measurements), or laws and guidance (regulatory). Many times, federal and individual state laws and guidance have specific mixing zone terms. A presentation of selected terms and their corresponding definition used in this report is presented in Table 1-3.

When a liquid effluent is discharged to a lake, a natural area of mixing is created. This area of mixing is where the effluent commingles with, spreads out, and disperses in the receiving water. Initially, mixing is driven by the hydraulic force of the water being discharged. This zone is defined as the jet entrainment zone. After the hydraulic energy of

the effluent is dissipated, differences in density and relative movement of the spreading effluent and the receiving water body combine for further mixing, described as the near-field mixing zone. Eventually, the natural currents of the receiving waterbody become the dominant force. This area is defined as the far-field mixing zone. As long as there are driving physical processes, such as density or temperature differences or differences in chemical concentrations, it is a physical reality that mixing between effluent and receiving water will proceed.

Regulations and guidance that allow a mixing zone have defined regulatory equivalents of the edges of the jet entrainment zone and the far-field mixing zone:

- Zone of Initial Dilution (ZID) is essentially equivalent to the jet entrainment zone of the near-field mixing zone,
- Total Mixing Zone (TMZ) is essentially equivalent to the combined near-field and far-field mixing zones.

These areas of mixing, adjacent to the discharge structure, are allocated zones that are designed and regulated so that rapid mixing occurs, assuring that the effluent quickly disperses in the receiving water.

Water quality criteria and Lake Michigan Standards based on Indiana Water Quality Standards are listed in Table 1-4 for metals and conventional constituents. Water quality criteria are defined by three factors:

- magnitude,
- duration, and
- frequency.

These factors are necessary to define criteria to protect the designated use of the waterbody. The criteria consider both the acute (short-term) effects and the chronic (long-term) effects. Short-term and long-term effects are measured through laboratory toxicity bioassay testing of a chemical. Acute criteria are based on protecting the most sensitive species from acute effects and are expressed as Acute Aquatic Criteria (AAC). For example, Indiana's AAC for chlorides is expressed as: 860 mg/L (magnitude) of chlorides as a one-hour (duration) average concentration not to be exceeded more than once every three years (frequency) on average. The Chronic Aquatic Criteria (CAC) are derived to protect the most sensitive species from chronic toxic effects and are expressed as a four-day average concentration. For example, Indiana's CAC for chlorides is expressed as: 230 mg/L (magnitude) of chlorides as a four-day (duration) average not to be exceeded more than once every three years (frequency) on average.

As interpreted by the USEPA 1991 *Technical Support Document for Water Quality-based Toxics Control* (TSD) and 1993 *Water Quality Standards Handbook* (WQSH) and stated in the Indiana WQS, the AAC and CAC, due to their duration (exposure) and frequency (time) elements, are to be met in the receiving water. To ensure protection of the receiving water, the point of application of criteria are:

- AAC at edge of the ZID, and
- CAC at the edge of the TMZ.

Indiana WQS also states that the Continuous Chronic Criteria (CCC), which includes the CAC, applies at the edge of the TMZ. The USEPA (1991 TSD and 1993 WQSH) has determined that travel time through an acute mixing zone (ZID) must be roughly less than fifteen minutes

if a one hour average exposure is not to exceed the acute criterion. In addition, USEPA has recommended receiving water flow or velocity design conditions to establish the mixing zone to mimic the three-year return interval. This type of assessment for receiving water quality addresses the magnitude (acute criteria concentration to be attained at edge of ZID), duration (rapid mixing of less than 15 minutes to minimize exposure), and frequency (critical/conservative receiving water velocity or flow) of exposure.

The Lake Michigan Standards (327 IAC 2-1-6(j)), expressed as "Daily Maximum" and "Monthly Average" limits, based on their regulatory history and scientific justification, should also be applied at the edge of the TMZ. The original intent of these standards was to gauge the quality of the south end of Lake Michigan as a source of drinking water prior to the passage of the Safe Drinking Water Act. The origin of the Lake Michigan standards is found in 1966 *Report of Water Quality Criteria, Calumet Area - Lower Lake Michigan* issued under the auspices of the Federal Water Pollution Control Administration (FWPCA). The report states, "... limits of constituents recommended by the Committee would be used as guides in judging the suitability of water quality for various uses ...". As stated in the FWPCA report, the "control points to judge compliance with the recommended criteria" for Lake Michigan in the vicinity of Amoco were "the Hammond Water Intake and the East Chicago Water Intake". Indiana adopted these standards and control points as SPC 4 through 8 in May 1967. The drinking water intakes are located several thousand feet offshore in waters defined, in later Indiana regulations, as "open" waters. Therefore, the application of these Lake Michigan Standards was clearly not intended to apply at the end of an effluent discharge pipe.

Federal Regulations and Guidance

Regulatory establishment of mixing zones first occurred in the late 1960's and early 1970's when thermal pollution from steam-electric power plants was of concern. During the 1970's, following establishment of discharge limitations based on the Federal Water Pollution Control Act of 1972, requirements and guidelines were issued to implement mixing zones that were environmentally protective. The mixing zone concept was applied more broadly, based on time and exposure assessments, to meeting effluent limitations placed on conservative constituents, such as total dissolved solids (TDS). During the 1980's, the definition and allowance of mixing zones were again expanded to include specific constituents for which USEPA had derived receiving water criteria. The USEPA ambient water quality criteria presented in the 1986 *Quality Criteria for Water* (or Gold Book) are the foundation for the Indiana Water Quality Criteria. As discussed previously, these criteria are based on magnitude (maximum and continuous), duration (acute - one hour or chronic - 4 days), and frequency (once per three years) statements. This process of integrating time and exposure with concentration was the basic scientific framework for assuring that mixing zones are protective to aquatic life. Part of the rationale for defining the point of application of acute and chronic receiving water criteria using a mixing zone was to allow a small area (where water quality standards do not apply) to exist without causing adverse effects to the overall waterbody. The delineation of a regulatory mixing zone was based on the two areas downstream from an outfall: ZIDs, outside of which no acute toxicity could occur, and total mixing zones, outside of which no chronic toxicity could occur. The purpose of this mixing zone definition was to minimize the area and time of exposure a wastewater discharge would have on the local biota.

In the 1990's, the USEPA reiterated its policy to allow mixing zones in streams, lakes, estuaries, and oceans for the application of water quality criteria. In the recently promulgated federal Water Quality Standards, 40 CFR 131, Subpart D, the applicability of mixing zones is recognized. Mixing zone concepts have been confirmed in various guidance documents such as the 1991 *Technical Support Document for Water Quality-based Toxics Control* (TSD), the 1993 *Training Manual for NPDES Permit Writers* (TMPW), and the 1993 *Water Quality Standards Handbook* (WQSH). These guidance documents presented revised and updated mixing zone concepts that reflected USEPA's policy of integrating effluent chemical characteristics, whole effluent toxicity, and receiving water bioassessments into the process of establishing water quality-based effluent limits. In addition, revisions were made as more scientific information was available on the relationship between time and exposure of organisms to constituents and the subsequent effects on the organisms and surrounding ecosystem.

The USEPA rules and guidance for mixing zones recognize that states may adopt mixing zones and specify the dimensions. As the water quality standards program elements were clarified by the USEPA, 49 States, including all the states bordering Lake Michigan, have promulgated regulations to demonstrate whether the use of a mixing zone for defining the point of application for a receiving water criterion is appropriate in a discharge permit. The states bordering Lake Michigan allow the use of mixing zones in the Lake on a case-by-case basis.

General Mixing Zone Characteristics

Individual mixing zones are unique to each effluent discharge and to each environmental setting. The mixing achieved from any effluent discharge can be described from the information listed below:

- Type of effluent discharge structure and configuration;
- Effluent physical characteristics (density, flow rate); and
- Receiving water hydraulic and physical characteristics (depth, velocity, density).

Each effluent plume can be characterized by identifying specific "regions" or areas within the mixing zone, although the location and configuration will differ for each plume. The pertinent regions of a mixing zone are:

- 1) Near-Field Mixing including:
 - a) Jet Entrainment Zone - Typically within a short distance downstream from the effluent discharge point resulting from initial momentum of the effluent into the receiving water. Dispersion is a function of the outfall characteristics.
 - b) Intermediate Mixing Zone - A combination of lateral and gravitational spreading and natural ambient diffusion that occurs during the transition from jet entrainment mixing to far-field mixing.
- 2) Far-Field Mixing Zone - Longitudinal, lateral and vertical mixing due to natural receiving water ambient diffusion. Mixing in this area is a function of receiving water characteristics.

Jet Entrainment Zone

The jet entrainment zone is the initial effluent mixing point in the receiving water. It represents the zone in which the maximum reduction in effluent concentration occurs. The size of the jet entrainment zone is directly related to the difference between initial effluent

velocity (flow) and the receiving water velocity in the discharge area as well as the initial density difference that exists between the effluent and the receiving water. The rate of dilution is quite rapid in the first few moments after exiting the discharge point. The width of the jet entrainment zone is related to the method of discharge with the average concentration across the plume cross section being about one-half to one-third the maximum centerline concentration. In this zone, designers of an outfall can affect the initial mixing characteristics through manipulation of outfall design variables. Multiport diffusers are designed so that each diffuser port will act as an individual plume for entrainment prior to merging. As presented in the USEPA 1991 TSD, the typical design effluent exit velocity from a diffuser port is around 10 ft/sec. For this velocity, the jet entrainment zone for a diffuser extends to about one diffuser length downstream¹ and the diffuser induced dispersion that can be obtained within this distance is on the order of a 50 to 100 times reduction of the effluent concentration. The reduction in effluent concentration based on the ratio of effluent concentration to receiving water concentration, as predicted or measured, will be referred to as the dispersion ratio in this report.

The regulatory term "ZID" is analogous to the jet entrainment zone. A typical definition for a ZID is a small area where rapid and immediate mixing occurs. The regulatory ZID definition should be flexible enough to allow the full jet entrainment zone to be utilized in any receiving water as this encourages use of discharge structures that maximize dispersion within a small area.

¹ Lee, J.H. and G.H. Jirka; "Multiport Diffuser as Line Source of Momentum in Shallow Water", Water Resources Research, Vol. 16, No. 4, pp 695-708.

Intermediate Mixing Zone

The intermediate mixing zone has several hydraulic factors acting on the effluent/receiving water mixing regimes. First, the effluent still has momentum that causes turbulent mixing with the receiving water. The plume also undergoes lateral gravitational spreading that occurs due to the density difference that may exist between the effluent and the receiving water. Additionally, the receiving water ambient diffusion forces are working to mix receiving water and effluent together. The overall mixing process continues at a much slower rate in this zone. The intermediate zone, where the effluent discharge still has influence, slowly transcends into the far-field mixing zone where the receiving water completely dominates the mixing.

Far-Field Mixing Zone

As the turbulent effluent plume travels farther away from the source, the effluent characteristics becomes less important. Far-field dispersion is totally dependent upon the receiving water ambient diffusion. Eventually, the effluent will become completely mixed laterally and vertically in the receiving water by natural ambient diffusion (far-field dispersive forces). The regulatory term of total mixing zone (usually defined in the far-field zone) is typically associated with the chronic toxicity limit (i.e., outside this zone, no chronic toxicity may occur) and is usually geographically limited. The distinction between near-field and far-field is made purely on a hydrodynamic basis. It is unrelated to any regulatory mixing zone definitions that address prescribed water quality standards.

Mixing Zone Specifications

The USEPA guidance documents recognize the use of mixing zones and state numerous mixing zone specifications. A summary of some of the specifications, including the goal of a mixing zone evaluation step and the information to be provided to answer the objective, is presented in Table 1-5. The focus of USEPA guidance includes:

- Determination of the mixing zone boundaries and analysis procedures;
- Minimization of the size of mixing zones;
- Prevention of lethality to passing organisms;
- Prevention of bioaccumulation problems;
- Recommendation of outfall design;
- Designation of critical design periods for water bodies; and
- Description of discharge induced mixing and ambient induced mixing modeling techniques.

The 1991 EPA TSD specifies that three independently established mixing zone specifications may apply, which include the following:

1. An immediate mixing zone, technically referred to as the jet entrainment zone, which is sized to prevent lethality to passing organisms. Acute criteria are met at the edge of this zone, and outside this zone no acute toxicity should occur to aquatic organisms. This zone is also known as the Zone of Initial Dilution (ZID).
2. A chronic mixing zone (or total mixing zone) is sized to protect the ecology of the waterbody as a whole. Chronic criteria are met at the edge of this zone, and outside this zone no chronic toxicity should occur to aquatic organisms.
3. A health criteria mixing zone is sized to prevent significant human risks. This typically implies that mixing zones not encroach on drinking water intakes nor result in significant health risks to average consumers who might uptake sufficient quantities of fish and shellfish that may be reasonably expected to

reside in the affected zone for sufficient exposure periods. These exposure periods would result in a net bioaccumulation of constituents that could subsequently result in a human health risk.

The mixing zone size may be limited by any single specification or all three of these specifications.

The 1991 TSD provides the guidance for assessing and defining mixing zones, the application criteria to mixing zones, and recommendations for outfall design. TSD Section 4, "Exposure and Wasteload Allocation", discusses assessment of mixing zones in receiving waters. In the overview, the EPA divides the transport of treated effluent in a waterbody into two stages:

- First - mixing and dilution as determined by the initial momentum and buoyancy of the discharge. As previously presented in this report, this is called the jet entrainment zone which is analogous to the Zone of Initial Dilution.
- Second - the area in which the effect of initial momentum and buoyancy is overridden and the wastewater is mixed primarily by ambient turbulence. In this report, this is the far-field mixing zone or total mixing zone.

The EPA does recommend that regulatory agencies evaluate mixing and outlines methods to evaluate dispersion and set mixing zones in Section 4 of the TSD. Several computer models are recommended for mixing zone analyses. These zone models were developed to divide the entire mixing region into several zones with distinct behavior (such as individual mixing processes in the near-field and in the far-field). All zone models require some schematization of the complex and arbitrary ambient and discharge conditions that may prevail at any discharge site. These schematizations are needed to conform to the requirements of the individual models. There are two main groups of zone models commonly used to evaluate

mixing: integrated zone models and jet integral models. The integrated zone model, 1992 Cornell Mixing Zone Expert System² CORMIX2, was used to evaluate the mixing between treated effluent discharged through a multiport diffuser and Lake Michigan. Modeling rationale is further discussed in Section 3.

The allowable size of a mixing zone is determined on a case-by-case basis, taking into account the critical resource area that needs to be protected and the assimilative capacity of the receiving water. As a mixing zone is used to define the point of application of receiving water criteria, it is necessary to first determine that the receiving water meets the criteria for its designated use. As presented in Table 1-4, average Lake Michigan background concentrations for this receiving water system are less than the concentrations allowed by the water quality criteria established to protect the use of Lake Michigan. These background concentrations were presented in the September 1992 IDEM report *Wasteload Allocation for the Grand Calumet River - Indiana Harbor Ship Canal* (WLA GCR-IHSC). This comparison between background concentrations and water quality standards confirms that the receiving water has available assimilative capacity.

INDIANA MIXING ZONE LAWS

Indiana has incorporated mixing zone specifications into its water quality rules since 1976. In March 1994, Indiana allowed the demonstration of site specific mixing zones for process water dischargers into Lake Michigan (IC 13-1-3-20), under conditions of IDEM

² Akar, P.J. and G.H. Jirka 1992. "CORMIX2: An Expert System for Hydrodynamic Mixing Zone Analysis of conventional and Toxic Submerged Multiport Diffuser Discharges", Technical Report, USEPA, ERL, Athens, GA.

approval. In addition, in the WLA GCR-IHSC report, IDEM recommended outfall effluent limitations based on the designated uses and criteria for the system, including part of the Indiana portion of Lake Michigan near the Amoco outfall. The background concentrations presented in Table 1-4 were used to perform the wasteload allocation for the system.

Section 2-1-6(a) of Title 327 specifies Water Quality Standards and Minimum Treatment Requirements Applicable to all state waters while Section 2-1-6(b)(5)(c), (j) and (k) specifically applies to all waters of Lake Michigan within the boundaries of the state of Indiana. The water quality standards presented in this Subsection (a) are derived from laboratory toxicity data for specific chemicals, translated to an in-stream application based on a duration and frequency assessment. Water quality limits specific to Lake Michigan are specified in 327 IAC 2-1-6(j) and are to be applied at the edge of the mixing zone based on their regulatory history. Lake Michigan ammonia and temperature criteria have already been stated to apply outside a mixing zone (327 IAC 2-1-6(b)(5)(C) and (k)(4)). Indiana defines a mixing zone as follows:

327 IAC 2-1-9 Definitions. "Mixing zone" means an area contiguous to a discharge where the discharged wastewater mixes with the receiving waters. Where the quality of the effluent is lower than that of the receiving waters, it may not be possible to attain within the mixing zone all beneficial uses which are attained outside the zone. The mixing zone should not be considered a place where effluent are treated.

Using the above definition, the high quality treated effluent discharged by Amoco, and the significant mixing occurring between the Amoco discharge and Lake Michigan, the physical existence of a mixing zone in this area has been established based on previous August 1991 field studies and computer modeling (discussed in Section 2). Guidelines in the Indiana Water

Quality Standards for demonstrating the application of a mixing zone in State waters are presented in the following paragraphs.

327 IAC 2-1-4 Mixing Zone Guidelines. "(a) All surface water quality standards in this rule, except those provided in section 6(a)(1) of this rule, are to be applied at a point outside of the mixing zone to allow for a reasonable mixture of waste effluent with the receiving waters.

(b) Due to varying physical, chemical, and biological conditions, no universal mixing zone may be prescribed. The commissioner shall determine the mixing zone upon application by the discharger. The applicability of the guidelines set forth in subsection (c) will be on a case-by-case basis and any application to the commissioner shall contain the following information:

- (1) The dilution ratio.
- (2) The physical, chemical, and biological characteristics of the receiving body of water.
- (3) The physical, chemical, and biological characteristics of the waste effluent.
- (4) The present and anticipated uses of the receiving body of water.
- (5) The measured and anticipated effect of the discharge on the quality of the receiving body of water.
- (6) The existence of the impact upon any spawning or nursery areas of any indigenous aquatic species.
- (7) Any obstruction of migratory routes of any indigenous aquatic species.
- (8) The synergistic effects of overlapping mixing zones or the aggregate effects of adjacent mixing zones.

(c) The mixing zone should be limited to no more than one-fourth (1/4) (twenty-five percent (25 %)) of the cross-sectional area and/or volume of flow of the stream, leaving at least three-fourths (3/4) (seventy-five percent (75 %)) free as a zone for a of passage for aquatic biota nor should it extend over one-half (1/2) (fifty percent (50%)) of the width of the stream.

(d) Based on consideration of aquatic life or human health effects, the commissioner may deny a mixing zone for a discharge or certain substances in a discharge.

(e) Notwithstanding other subsections of this section, no mixing zone shall be allowed for discharges to lakes except for those consisting entirely of noncontact cooling water which meet the requirements set forth in Section 316(a) of the Federal Water Pollution Control Act of 1972."

On March 18, 1994, the Indiana General Assembly enacted House Enrolled Act 1126 which includes IC 13-1-3-20 as follows:

IC 13-1-3-20. (a) "Notwithstanding any rules of the board, the commissioner shall allow for a mixing zone in permits that involve a discharge into Lake Michigan if the applicant can demonstrate to the commissioner that the mixing zone will not cause harm to human health or aquatic life.

(b) For mixing zones allowed under subsection (a), surface water quality standards for bioaccumulative chemicals of concern shall be applied to the undiluted discharge, rather than at a point outside the mixing zone."

As presented in Table 1-5, the Indiana guidelines reflect USEPA guidance for specifying mixing zones and for the demonstration that a mixing zone is protective of the receiving waters (lakes and streams). Consequently, under Indiana law, Amoco is applying for a mixing zone and is presenting the necessary information to demonstrate that implementation of a mixing zone is appropriate.

APPLICABILITY OF MIXING ZONE FOR THE AMOCO WHITING REFINERY

The Amoco Whiting Refinery is seeking to demonstrate to the State of Indiana that implementation of a mixing zone to assure attainment of receiving water quality requirements is applicable since:

- Implementation of a mixing zone for the Amoco facility is not a substitute for BAT wastewater treatment;
- The Federal Clean Water Act does not require attainment of receiving water quality criteria at end-of-pipe;
- The proposed mixing zone covers a limited area and will not impair the integrity of the receiving waterbody;
- Acute toxicity has not been observed using EPA test methods; that is, Amoco Outfall 001 effluent has not been acutely toxic;

- Implementation of a mixing zone will reduce the need for excessive unnecessary wastewater treatment;
- Amoco is not seeking a mixing zone for Indiana-defined bioaccumulative substances; and
- Using Indiana mixing zone guidelines which are similar to USEPA mixing zone directions, a mixing zone in Lake Michigan can be defined that will not cause harm based on consideration of aquatic life and human health.

TABLE 1-5. FEDERAL AND INDIANA MIXING ZONE SPECIFICATIONS

GOAL	OBJECTIVE	APPROACH	INFORMATION/RESPONSE
Ideally, holistic concepts to determine that a mixing zone is protective. ^{a,d}	Consider all the impacts to the water body and the impacts that the small area of decreased water quality within the mixing zone will have on the surrounding ecosystem and water body uses. ^{a,d}	Use a multistep data collection and analysis procedure. - Identify all ecological and cultural data for upstream and downstream water bodies; collect data on all present and future discharges to the water body; assess relative environmental value and level of protection needed for the water body; allocate environmental impact for a discharge applicant. ^{a,d}	Background water quality conditions. (Federal ^{a,c,d} and Indiana ^{a,g}) Present and anticipated use of receiving water. (Indiana ^a) Measured and anticipated effect of discharge on receiving water quality. (Federal ^{a,c,d} and Indiana ^a) Will not cause harm to aquatic life and human health. (Indiana ^{a,h})
Waterbody integrity protected, maintained, and restored. ^{a,b,c,d,e}	Assimilative capacity available. ^{a,c,d,i}	Consider desired uses of water and criteria for use. ^{a,c,d,e}	Background water quality - physical, chemical and biological. (Federal ^{a,c,d} and Indiana ^{a,g}) Present and anticipated uses of receiving water. (Indiana ^a) Measured and anticipated effect of discharge on receiving water quality. (Federal ^{a,c,d} and Indiana ^a) Mixing zone should not be considered a place where effluent is treated, that is technology-based limits achieved. (Indiana ^{a,i})

AUGUST 24, 1994

TABLE 1-5. FEDERAL AND INDIANA MIXING ZONE SPECIFICATIONS

GOAL	OBJECTIVE	APPROACH	INFORMATION/RESPONSE
Waterbody integrity protected, maintained, and restored. ^{a,b,c,d,e} (Continued)	Protect critical areas. ^{a,d,e}	Consider location of mixing zone. ^{a,c,d,e}	<p>Location of mixing zone does not extend to drinking water intake. (Federal^{a,c,d})</p> <p>Impact on spawning and nursery areas. (Indiana^a)</p> <p>Size, shape, and location of mixing zone. (Federal^{a,c,d})</p> <p>Mixing zone boundaries. (Federal^{a,c,d} and Indiana^{a,g})</p> <p>Mixing zone does not block passage of aquatic life. (Federal^{a,c,d} and Indiana^a)</p> <p>Mixing zone does not promote undesirable aquatic life. (Federal^e)</p> <p>Substrate characteristics and geomorphology: impact of mixing zone on sessile organisms. (Federal^{a,c,d})</p>
Waterbody integrity protected, maintained, and restored. ^{a,b,c,d,e} (Continued)	No lethality to passing organisms. ^{a,b,d}	Minimize size of elevated concentration isopleths within the mixing zone. ^{a,b,d}	<p>Degree of discharge induced mixing. (Federal^{a,b,c,d} and Indiana^a)</p> <p>Mixing zone shall be free of substance or combination of substances that are acutely toxic. (Indiana^a)</p>

AUGUST 24, 1994

TABLE 1-5. FEDERAL AND INDIANA MIXING ZONE SPECIFICATIONS

GOAL	OBJECTIVE	APPROACH	INFORMATION/RESPONSE
Definable mixing zone extent and magnitude. ^{a,c,d}	Define application point for short-term and long-term aquatic criteria, i.e., AAC or TU _a at edge of ZID, CAC or TU _c at the edge of TMZ. ^{a,b,c,d,e}	Spatial definitions and achievement rapid immediate mixing. ^{a,d,e}	Mixing zone location, size, shape, boundaries, and dilution ratio. (Federal ^{a,c,d} and Indiana ^a) In lakes, a circle with a specified radius is preferred. (Federal ^a) Manner (outfall design) on which diffusion/dispersion occurs. (Federal ^{a,c,d}) Maximize initial dilution. (Federal ^a) Location where discharge-induced mixing ceases in lakes. (Federal ^a) Physical, chemical, and biological characteristics of effluent. (Indiana ^a)

Federal References:

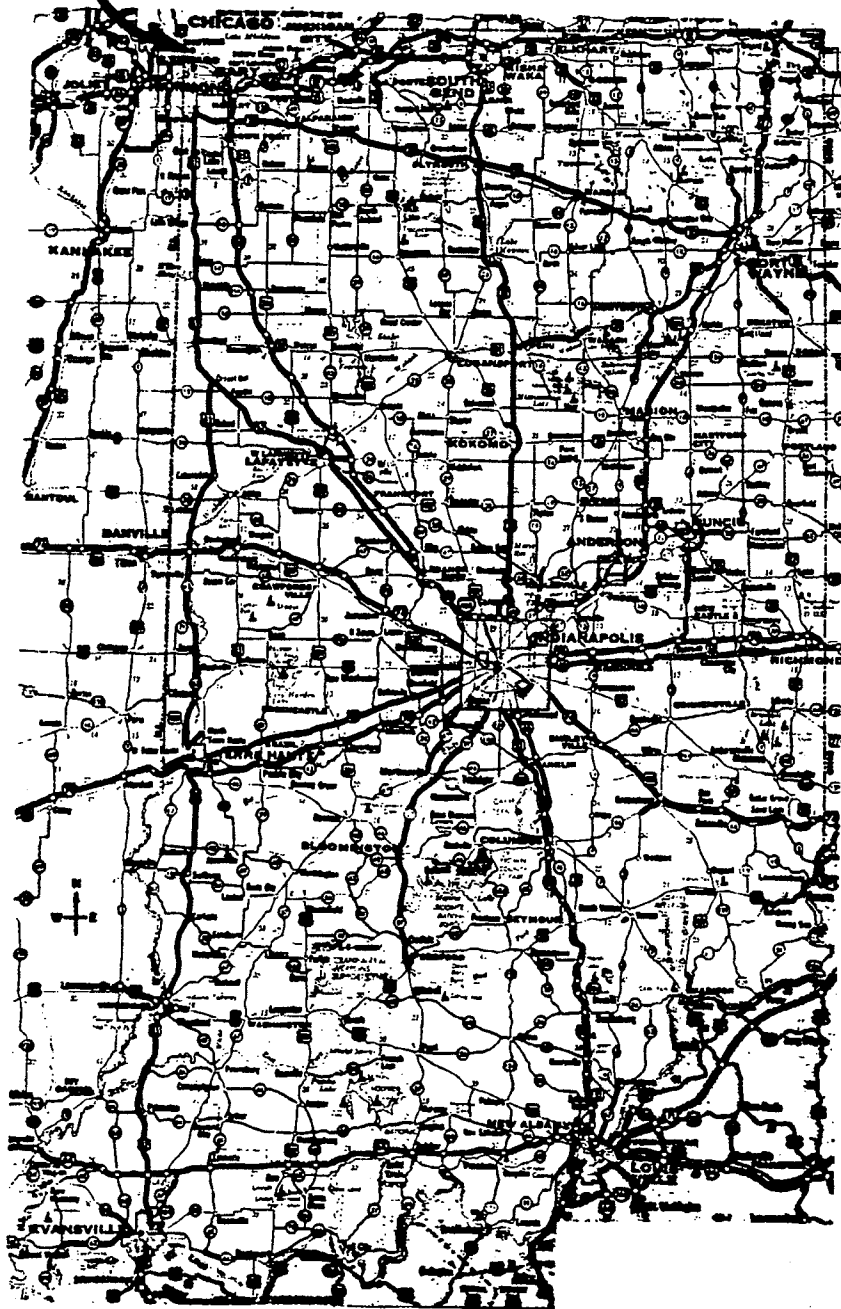
- (a) USEPA, March 1991, *Technical Support Document for Water Quality-based Toxics Control*, USEPA/505/2-90-001. (TSD).
- (b) USEPA, March 1993, *Training Manual for NPDES Permit Writers*, USEPA 833-B-93-003. (TMPW)
- (c) USEPA, April 16, 1993, "Proposed Water Quality Guidance for the Great Lakes System", 58 Federal Register, 20802-21047. (GLI)
- (d) USEPA, September 1993, *Water Quality Standards Handbook*, Second Edition, USEPA 823-B-93-002. (WQSH)

Indiana References:

- (e) 327 IAC 2, *Water Quality Standards*.
- (f) 327 IAC 5, *Industrial Wastewater NPDES and Pretreatment Programs*.
- (g) IDEM, OWM, 1993, Proposed Technical Release OWM-1, "Procedure for Developing Water Quality-based NPDES Permit Limitations for Toxic Pollutants". (OWM-1)
- (h) IC 13-1-3-20

AUGUST 24, 1994

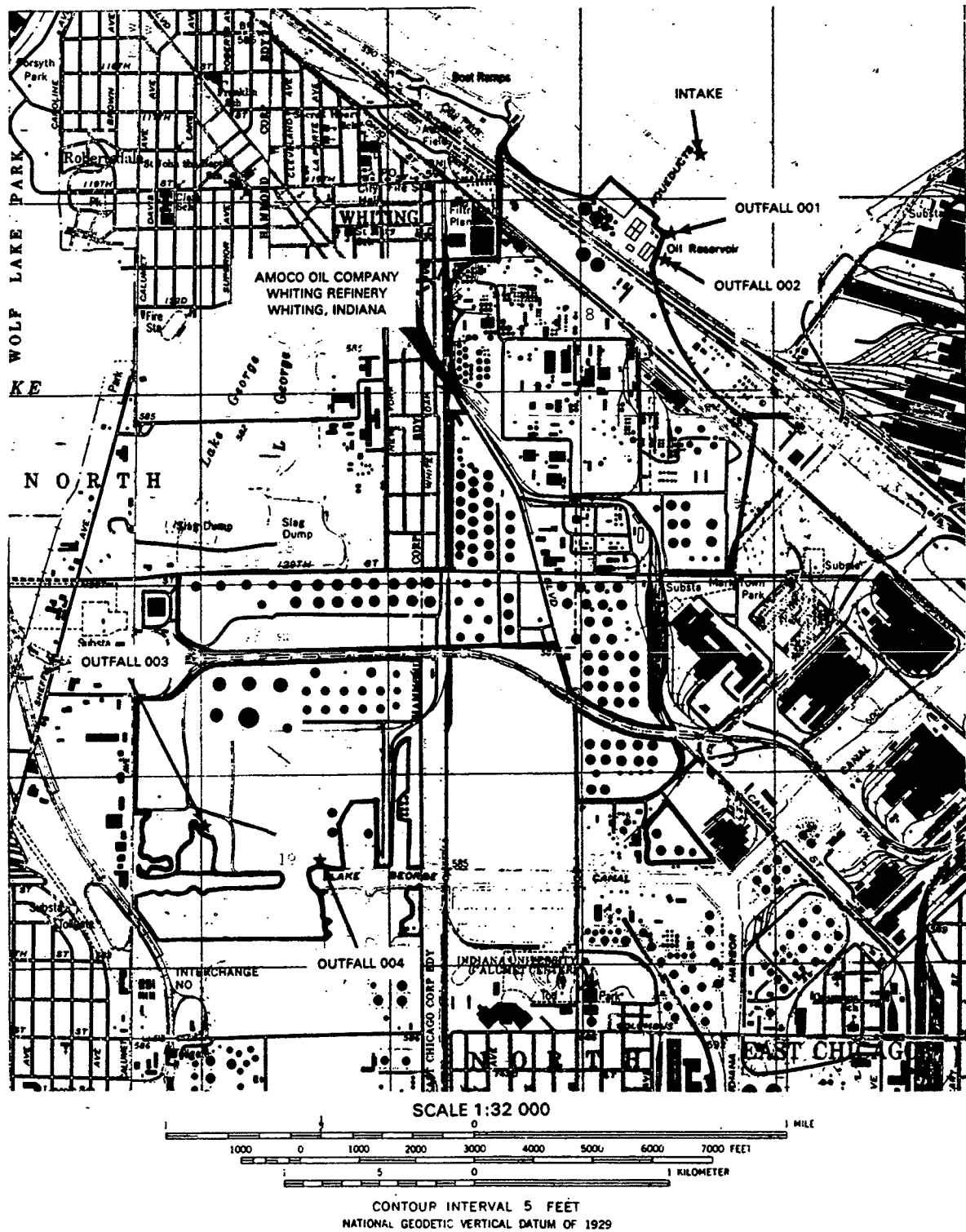
**AMOCO OIL COMPANY - WHITING REFINERY
WHITING, INDIANA**



**FIGURE 1-1
LOCATION MAP
WHITING, INDIANA**

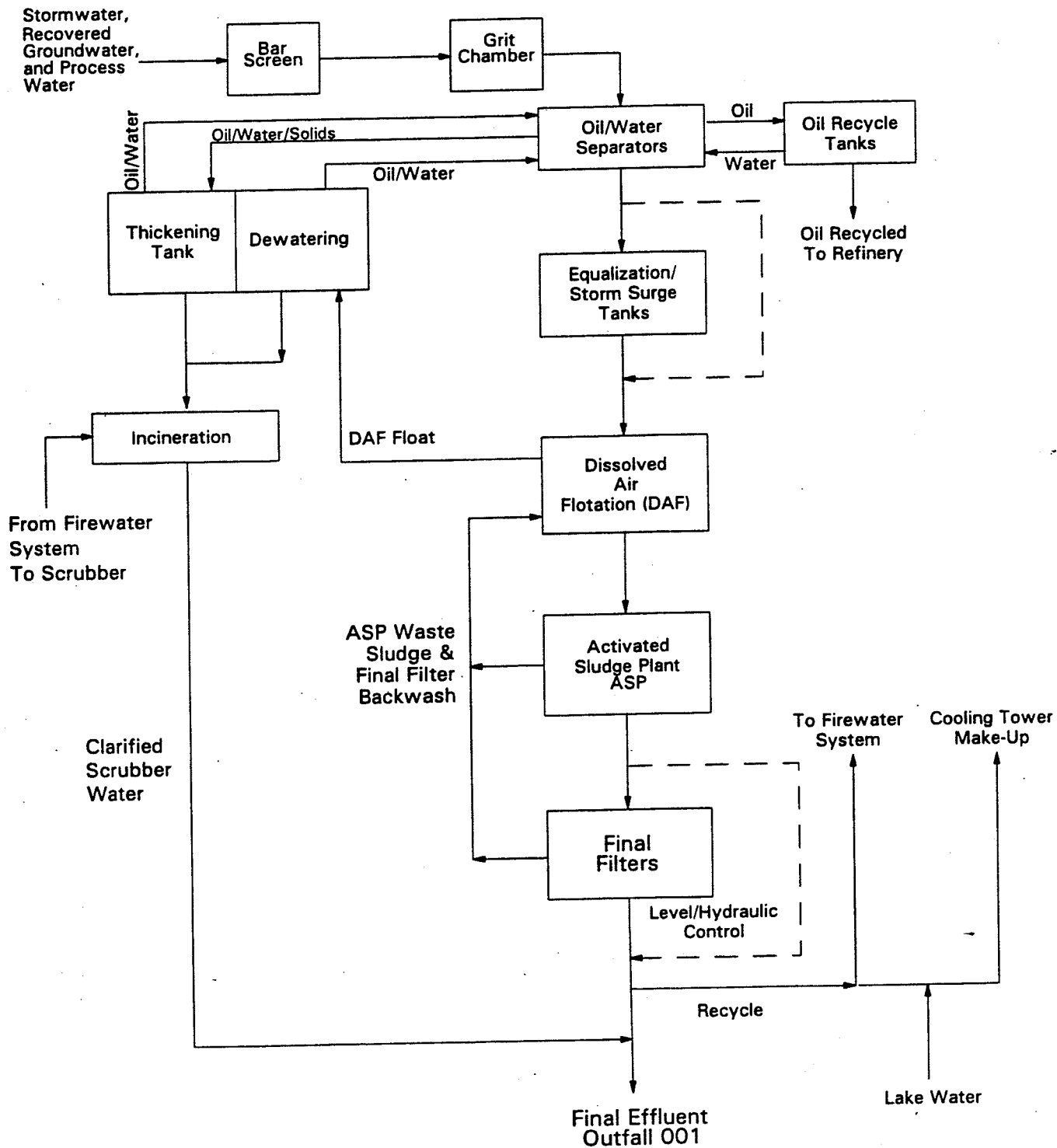
AUGUST 24, 1994

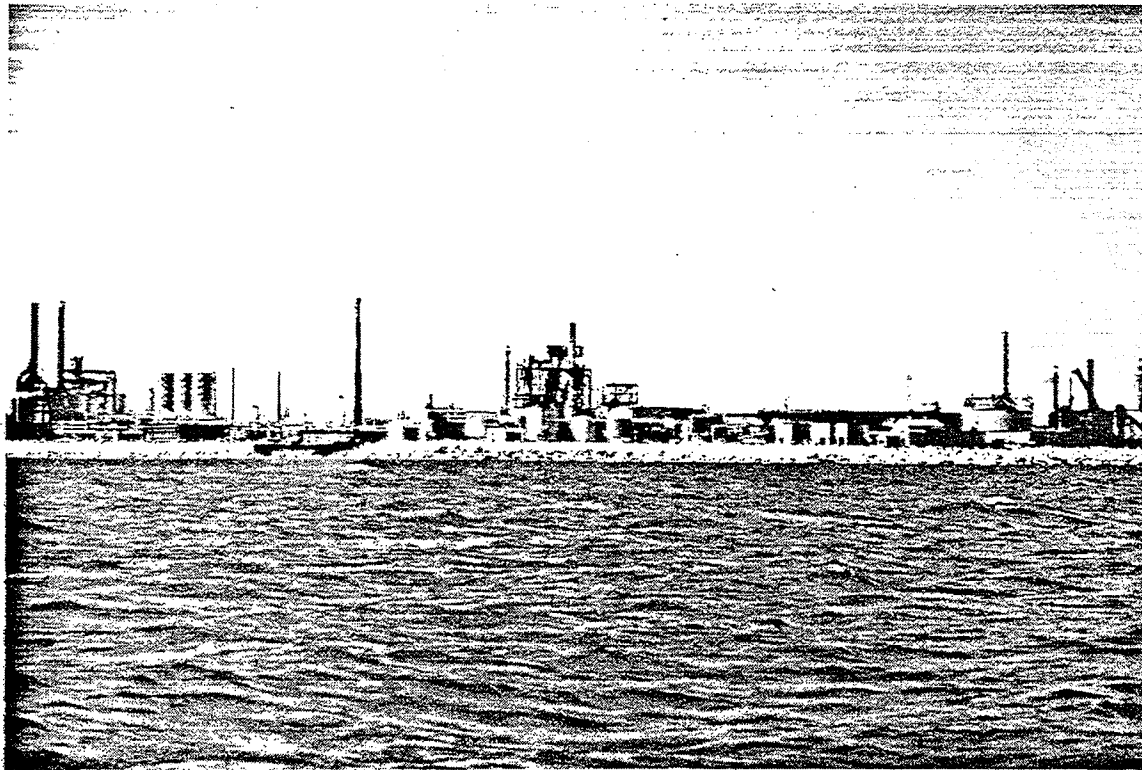
**FIGURE 1-2
AREA MAP
AMOCO OIL COMPANY - WHITING REFINERY**



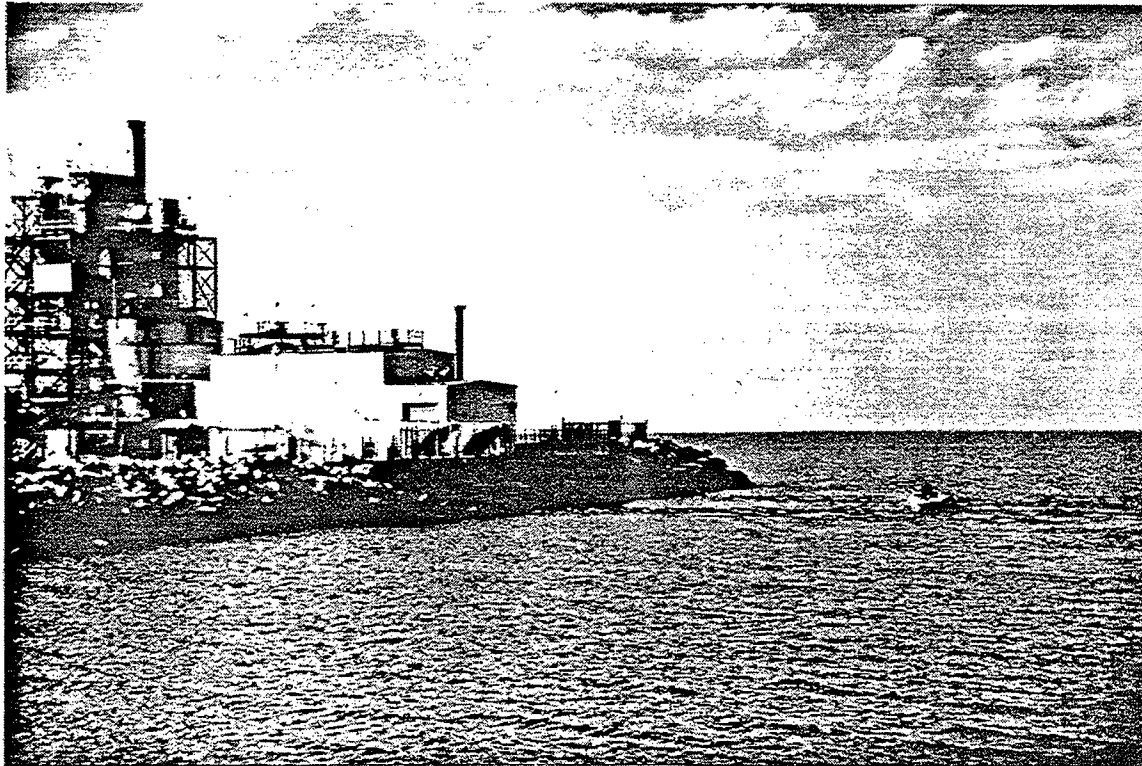
SOURCE: USGS 7.5 min. TOPOGRAPHIC MAPS LAKE CALUMET ILL. AND WHITING, IND. 1991

FIGURE 1-3
WASTEWATER TREATMENT PLANT - WATER FLOW DIAGRAM
AMOCO OIL COMPANY - WHITING REFINERY



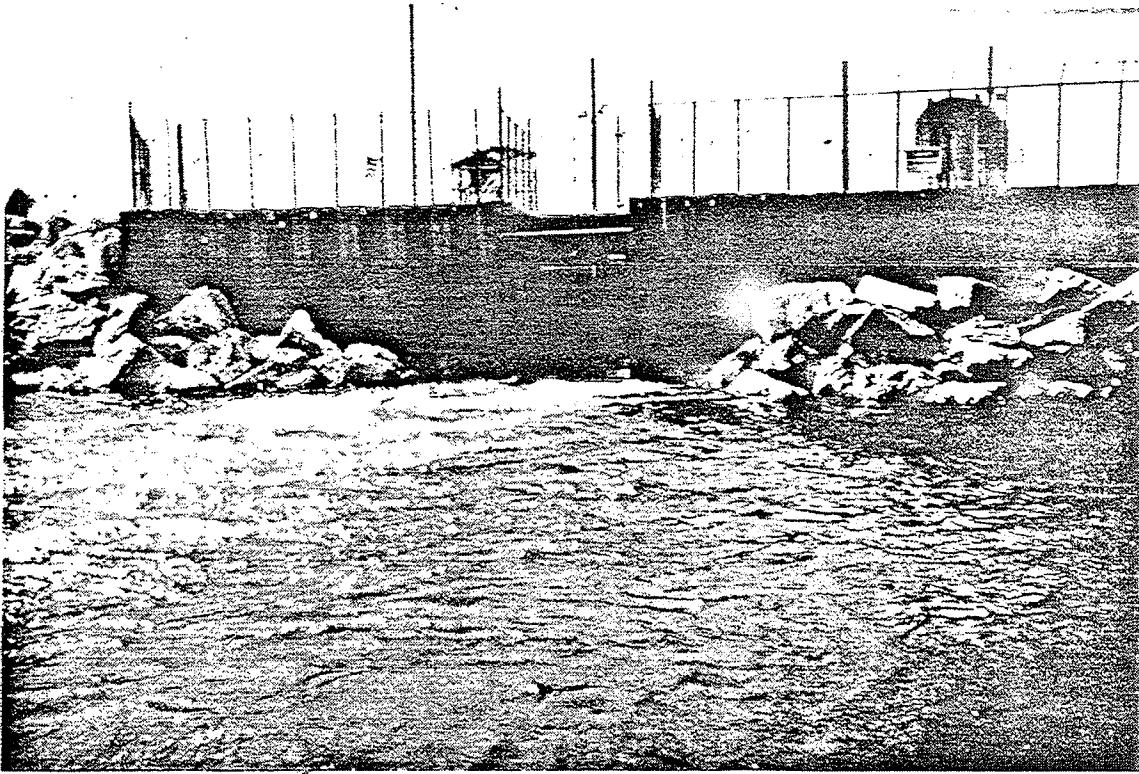


Looking Toward Amoco Lakefront Wastewater Treatment Plant Outfalls Located On-Shore, Photo Center Left

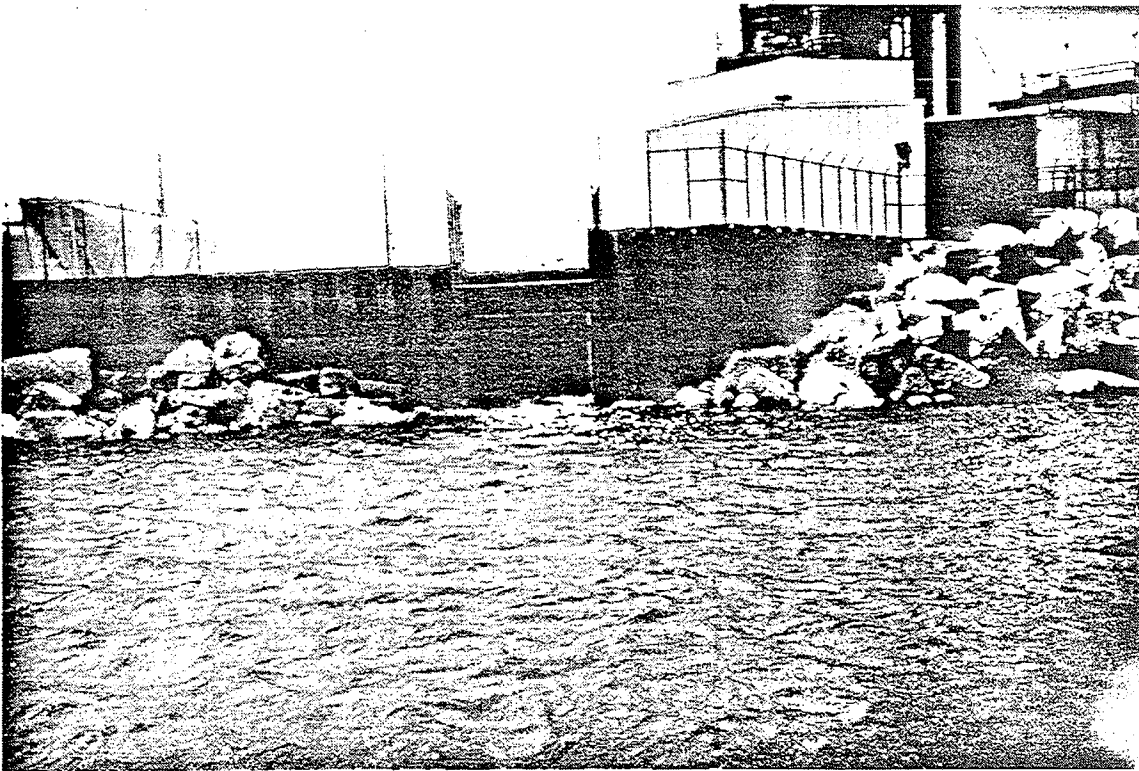


Looking From Shore Towards Lake Front and Lake Michigan Outfalls at Photo Center Left

FIGURE 1-4



Outfall 002 Viewed From Lake



Outfall 001 Viewed From Lake

FIGURE 1-5

